The case for prior cryo-conditioning in the Highlands of S. E. Australia

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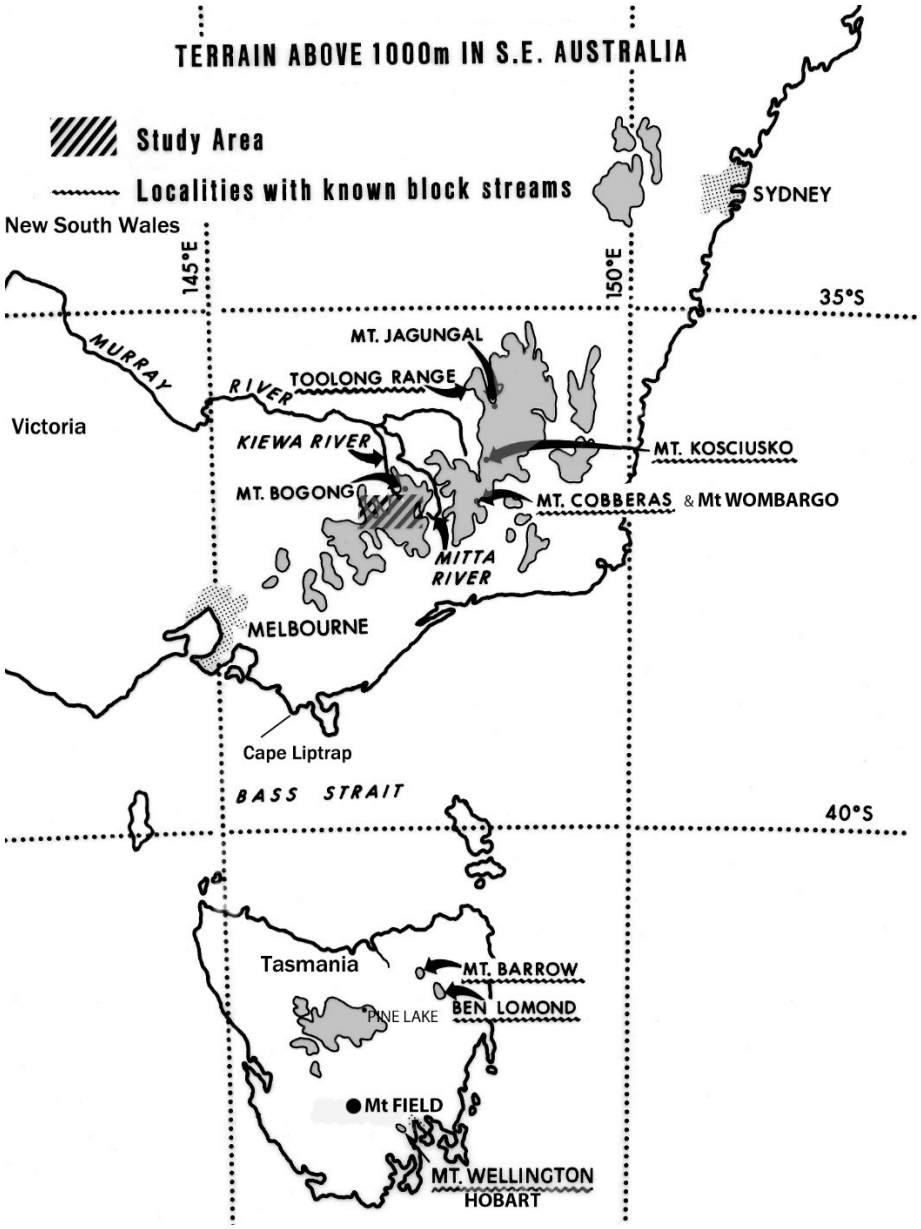
Abstract

A summary of evidence for prior cryo-conditioning in S. E. Australia.

Keywords: cryo-conditioning, permafrost, frost creep, gelifluction, blockslopes, blockstreams.



The Highlands of southeastern Australia possess a set of relict features which are consistent with prior permafrost and cryo-conditioning during the late Pleistocene. Data is summarized for specific examples in table one. The following figures are numbered for each column (location) in table one. Cryo-conditioning[1] is the modification of portions of these landscapes which possess susceptible bedrock and surface debris due to interaction with a thermal regime causing prolonged subsurface temperatures <0^{o}C, except for the seasonal thawing of the uppermost layer, the active layer.

Permafrost creep is the slow downhill mobilization of frozen, ice-rich debris and it has been the focus of research for the task force (in Europe) on Permafrost Creep and Rock Glacier Dynamics, since 1998. Wilfried Haeberli (2006)[2] reported on the nature of permafrost creep, its associated stratigraphy and its morphology. The stratigraphy/morphology of creeping permafrost, especially the active layer, correlate well with the open blockwork of relict blockslopes and blockstreams in the Australian Alps.

Haeberli (2006) and others have reported that steadily creeping perennially-frozen, ice-rich debris in mountain areas outside the arctic circle, possess an active layer which develops vertical sorting, with grainsize decreasing with depth. Corte (1966)[3] demonstrated the process of vertical sorting in the laboratory and also in field trials in permafrost terrain. Most relict block deposits with coarse, open, sub-angular debris at the surface, in the Australian Alps, exhibit vertical sorting with fining towards the base. A selection of these deposits is outlined in table one.

The term periglacial is not only vague, it lacks the context of adjacent glacial landforms in Victoria and it also lacks a specific signature on the landscape because the periglacial domain represents a broad range of environmental conditions. However, when Colin Thorn (2004)[4] asserted that freeze-thaw weathering lacks diagnostic characteristics, he may not have fully considered the textural effects of a sub-zero thermal regime on well jointed bedrock.

Vertical sorting of debris generated in a sub-zero thermal regime has been reported in mountain permafrost zones throughout the northern hemisphere by: Wahrhaftig (1949)[5],

Krane and Mostler (2000)[6], Haeberli et al (2006), Hausmann et al (2007)[7] and Leopold et al (2011)[8]. Vertical sorting of relict blocky deposits in the highlands of southeastern Australia is well documented by Caine and Jennings (1968)[9] on the Toolong Range, Kosciuszko National Park and also within the blockfields of Ben Lomond and Mt Barrow by Nel Caine (1968)[10]. Vertical sorting has also been observed within a block glacis at Basalt Hill by Minty (2018)[11] and within an exposed road section near Betts Creek, Kosciuszko National Park, (Minty 2021)[12]. Vertical sorting is evident in road sections through relict blockslopes on the northern slopes of Ben Lomond and Mt Barrow (Minty 2021)[13]. Also, sieving of auger returns extracted from a suspected relict gelifluction layer on Mt Nelse (1882m) on the Bogong High Plains, Victoria has revealed vertical sorting of material in a small grainsize range from cobbles to fine sand[14].

In addition to vertical sorting, the relict blockstreams and blockslopes of S.E. Australia possess other characteristics which are consistent with prior cryo-conditioning

i) Lateral Displacement. In most cases it can be demonstrated that lateral displacement of blockwork on gentle-moderate slopes (< the angle of repose) has occurred, for up to 1000m beyond the source bedrock boundaries.

ii) Thermokarst. This is the surface morphology resulting from the melt-out of interstitial/included ice from within the blockstreams/blockslopes. It seems to take several forms including: a) Broad deflation of the blockstream resulting in a concave cross-section. b) Furrows or linear depressions running downslope for tens or hundreds of metres and from 1 to 3m deep. These furrows are dendritic in plan and mimic an underlying drainage network. c) Pits or conical-broad depressions from 600mm deep to approx. 3m deep in large deposits.

iii) Imbrication is the regular stacking of tabular or platy blocks in a blockstream/blockslope, like a set of dominoes that have toppled downslope and onlap onto each other. This fabric suggests episodic movement consistent with seasonal thawing and fluidization of the active layer.

iv) Context. Other adjacent relict landforms. Frost heaved blocks of jointed bedrock on exposed, elevated bedrock surfaces are common in association with blockslopes down-slope. Also, these exposed ridges and summit flats generally exhibit terraced bedrock with a stepped profile. These features are consistent with cryoplanation in permafrost terrain as reported by Washburn (1975)[15] and illustrated for the Bogong High Plains[16].

v) Palaeoclimate Proxies. These studies are discussed in the book: *Kosciuszko Ice-Age Heritage*. They all point to cycles of very cold and very dry, windy conditions during the late Pleistocene with increasing aridity culminating at 17ka-22ka BP, when most of the blockslopes/blockstreams in S. E. Australia were last active[17].

Nel Caine (1983) reviewed his earlier work in northeastern Tasmania and concluded that the low gradients of the associated blockslopes was probably due to permafrost creep during the late Pleistocene[18].

Table One: **A Selection of relict cryogenic landforms consistent with prior permafrost in southeastern Australia**

Location	Mt Field Tasmania	Sphinx Bluff, Ben Lomond, Tasmania	Carr Villa, Ben Lomond, Tasmania	Pine Lake, Tasmania	Basalt Hill, Bogong High Plains, Victoria	Mount Wombargo Eastern Victoria	Mount Little Higginbotham Victoria	Section Ridge, KNP, NSW	Toolong Range, KNP, NSW	Farm Ridge, KNP, NSW	Spencers Creek, KNP, NSW	Mount Kosciuszko KNP, NSW
Major Features	Blockslope & Rockglacier (Relict)	Blockslope & Rockglacier (Relict)	Compound Blockslope (Relict)	Blockslope & Block Glacis/ Relict Rockglacier	Blockslopes & relict Compound blockstreams	Vegetated Blockslopes, Blockstreams (Relict)	Blockslope & Block glacis (Relict)	Blockstreams & Blockslopes (Relict)	Blockstreams & vegetated blockslopes (Relict)	Blockslopes & Blockstreams (Relict)	Blockslope & Block glacis (Relict)	Blockslopes & Blockstreams (Relict)
Specific Location	146°37.911'E 42°40.732'S	147°44.0'E 41°36.529'S	147°37.836'E 41°30.811'S	146°44.823'E 41°42.284'S	147°19.200'E 36°53.644 'S	148°9.876'E 36°57.101'S	147°9.660'E 36°59.544'S	148°24.574'E 35°49.874'S	148°21.513'E 36°8.036'S	148°23.535'E 36°4.151'S	148°19.976'E 36°25.960'S	148°15.496'E 36°27.233'S
Elevation Range	880-1140m	1130-1330m	1247-1360m	1190-1300	1430-1640m	1256-1510m	1548-1730m	1073-1230m	1630-1670m	1430-1545m	1757-1780m	1960-2090m
Rock type	Dolerite	Dolerite	Dolerite	Dolerite	Basalt	Rhyodacite	Basalt	Basalt	Basalt	Basalt	Granodiorite	Granodiorite
Rock Structure	Columnar max diam 2m	Columnar	Columnar max diam 2m	Columnar max diam 2m	Columnar max diam 0.5m	Columnar Max diam 1.0m est.	Columnar	Columnar max diam 1.0m	Columnar max diam 0.5m	Columnar	Tabular blocks to 4m	Tabular blocks to 4m
Gradient and Morphology	60% blockslope merges into a lobate terrace 20%	36% blockslope merges to compound lobes at 25%	64% at head to 20% at toe.	35% blockslope merges with 20% block glacis/R.R.	Dendritic, discont. Blockstreams ave grad. 25% - 46%	33-38%grad. Dendritic set of blockstreams Concave x-s	Block glacii merge to blockslope with ave grad. 45-50%	Stepped blockstream Grad. mostly 33%-50%. Risers to 84%	Rectilinear blockstreams at 8%-15% with distal risers at 47%	Concave slope with ave gradient 30%. Long. Furrows	Blockslope 20-25% & distal block glacis 2-10%	Blockstream gradient 22% over 550m
Surface Texture	Imbricated blocks. Thermokarst pits 3m deep	Imbricated blockwork. Traces of transverse ripples	Imbricated blockwork; Thermokarst pits 3m deep.	Imbricated blockwork, Thermokarst; Transverse Ripples.	Imbricated; Vert. sorting; Transverse Ripples & pits to 1.0m	Open blockwork	Imbricated blockwork, Transverse Ripples, & pits to 1.5m	Imbricated blockwork, Transverse Ripples, & Thermokarst	Imbricated, Longitudinal Furrows to 2m & pits to 1m	Traces of transverse lobes in distal blockstream	Imbricated; broad vegetated depressions to 2-3m	Imbricated blockwork. Terraced bedrock Cryoplanation
Age	Late Pleistocene (Inferred)	Late Pleistocene (Inferred)	22.1ka-498ka Radiometric Exposure dating	Late Pleistocene (Inferred)	Late Pleistocene (Inferred)	Late Pleistocene (Inferred)	16.3ka-58.9ka radiometric	21.3ka-22.7ka radiometric	<35ka C14 dating	Late Pleistocene (Inferred)	Late Pleistocene (Inferred)	Late Pleistocene (Inferred)
Authors Referred to	Minty, 2021, Report on cryogenic features at Mt Field.... **Academia**	Nel Caine, 1983 The Mountains of NE Tasmania Note pp112-114	Barrows et al 2004, Quaternary Science Reviews, V23	Minty,2021 Relict Cryogenic Landscape at Pine Lake, **Academia**	Minty,1989 MSc thesis, Abstract pub. Roy Soc NSW V 123, 1990	Reference to J. A. Talent, 1965. Proc Roy Soc Vic V78	Barrows et al 2004, Quaternary Science Reviews, V23	Barrows et al 2004, Quaternary Science Reviews, V23	Caine & Jennings, 1968, Proc Roy Soc NSW, V101	Minty, 2021 Koscluszko Ice-Age Heritage. **Academia**	Minty, 2021 Koscluszko Ice-Age Heritage. **Academia**	Minty, 2021 Koscluszko Ice-Age Heritage. **Academia**

Figure 1 Mt Field , Tasmania

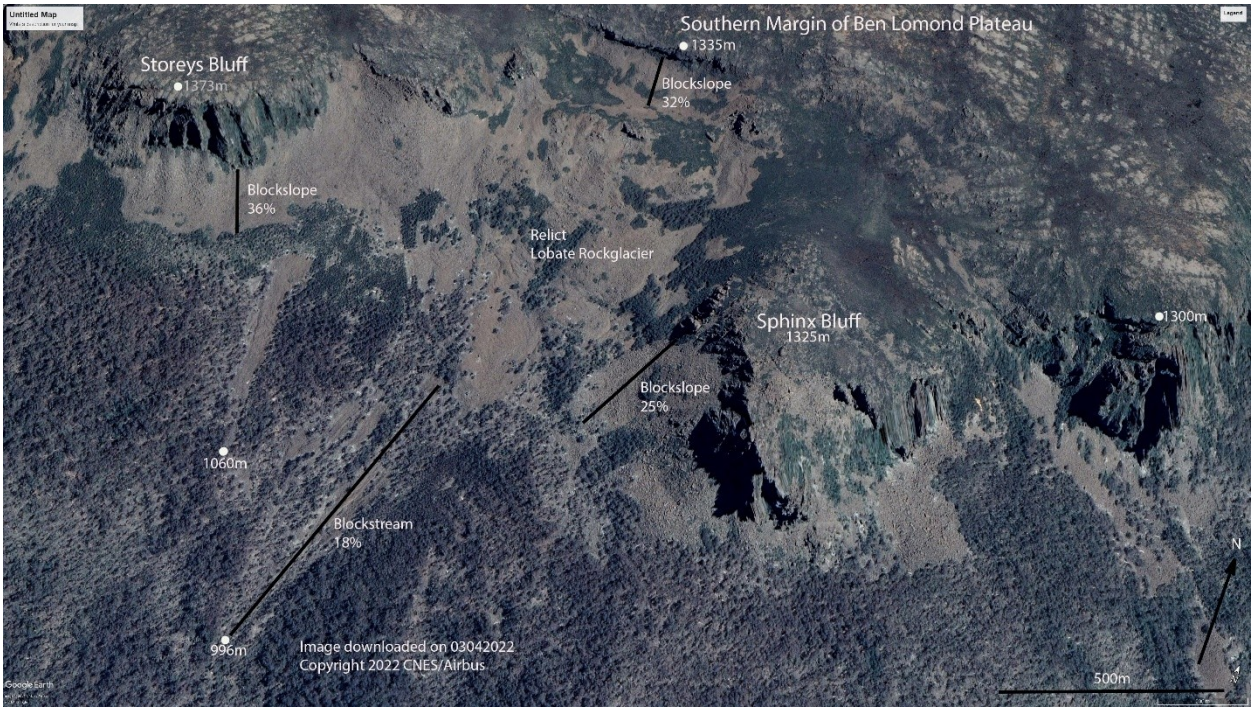


Figure 2 Sphinx Bluff, Blockfields and relict Lobate Rockglacier, Ben Lomond, Tasmania

Figure 3a Distal Toe of Carr Villa Blockslope, Ben Lomond, Tasmania

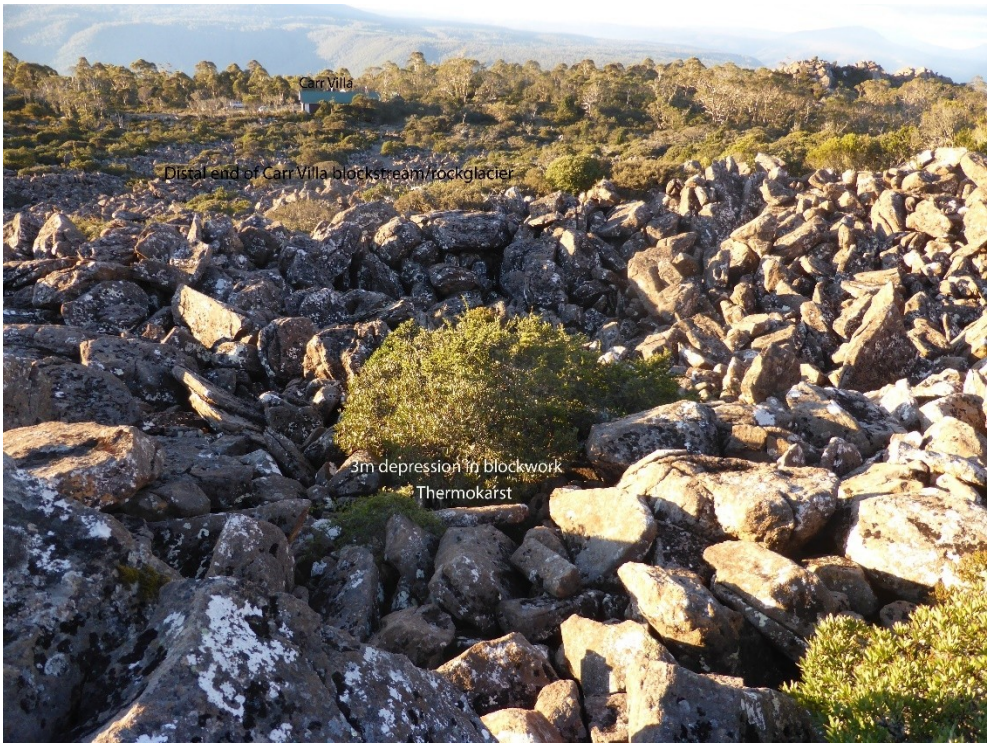


Figure 3b Thermokarst depression in blockwork on Carr Villa Blockslope, Ben Lomond.

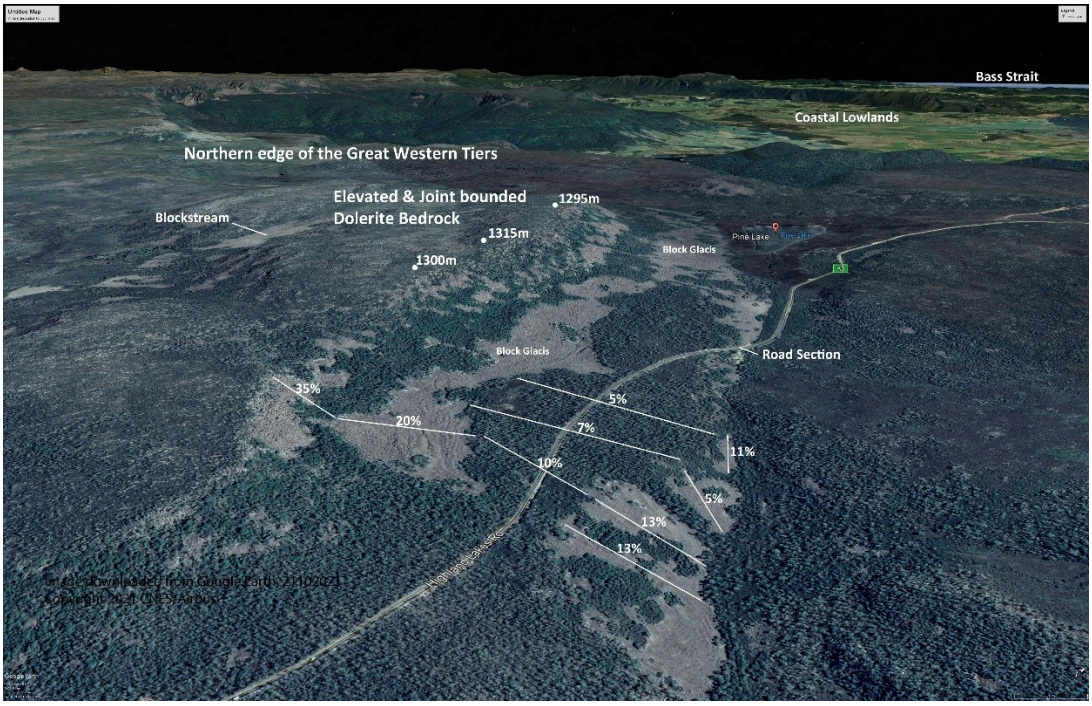


Figure 4 Overview of Blockslope terrain near Pine Lake, Tasmania

Figure 5 Overview of Basalt Hill Blockstreams on the Bogong High Plains, Victoria

Figure 6 Dendritic blockstreams SW of Mt Wombargo in eastern Victoria

Figure 7a Overview of block glacis and blockslope below Mt Little Higginbotham, northeastern Vic.

Mt Little Higginbotham Blockslope
LHB 07
Dry Stone Wall at Toe of Blockstream
(LHB 07 is the approx position of a block sampled by Barrows et al. 2004 dated at 8k 9Ka)
Aqueduct constructed about 1870

Figure 7b View up Blockslope with aqueduct in foreground

Figure 8 Steep, narrow blockstream below Section Ridge, Kosciuszko National Park, NSW.

Figure 9 Overview of the Blockstreams investigated by Caine & Jennings, 1968, KNP.

Figure 10 Blockstreams below the SE edge of Farm Ridge, Kosciuszko National Park, NSW.

Figure 11a Blockslope/Block Glacis at head of Spencers Ck and below Mt Guthrie, KNP.

Figure 11b View of imbricated granodiorite blocks in blockslope below Mt Guthrie, KNP.

Figure 12 Blockstreams and vegetated blockslopes on western flank of Mt Kosciuszko, KNP.

[1]**References**

Berthling I. (2011) The concept of cryo-conditioning in landscape evolution. *Quaternary Research* **75:** 378-384.

[2] Haeberli W. et al (2006). Permafrost and Rock Glacier Dynamics, *Permafrost and Periglacial Processes*,**17**: 189-214.

[3] Corte A. E., (1966). Particle Sorting by Repeated Freezing and Thawing. *Biuletyn Peryglacjalny* **15**:175-240.

[4] Thorn C. E. (2004). Whither, or Wither, Periglacial Weathering Studies? *Polar Geography* **28**/1:4-12.

[5] Wahrhaftig C., (1949). The Frost-Moved rubbles of Jumbo Dome and their significance in the Pleistocene Chronology of Alaska, *The Journal of Geology,* **2**: 216-231.

[6] Krainer K., Mostler W., (2000). Reichenkar Rock Glacier: A Glacier derived debris-ice system in the western Stubai Alps, Austria. *Permafrost and Periglacial Processes* **11:**267-275

[7] Hausmann H., Krainer K., Bruckl E. & Mostler W (2007) Internal Structure and Ice Content of Reichenkar Rock Glacier (Stubai Alps, Austria) Assessed by Geophysical Investigations. *Permafrost and Periglacial Processes* **18**: 351-367.

[8] Leopold M., Williams M. W., Caine N. Volkel J. & Dethier D. (2011) Internal Structure of the Green Lake 5 Rock Glacier, Colorado Front Range, USA, *Permafrost and Periglacial Processes* **22**: 107-119.

[9] Caine N. & Jennings J. N., (1968), Blockstreams of the Toolong Range Kosciuszko State Park, New South Wales, *Proceedings, Royal Society of New South Wales* **104**: 93-103.

[10] Caine N. (1968), *The Blockfields of Northeastern Tasmania*, Research School of Pacific Studies, Australian National University, Department of Geography publication **G/6**: 1-127.

[11] Minty E. J., (2018) unpublished investigation, included in: *Kosciuszko Ice-Age Heritage*, published on-line with Academia.edu, note discussion of vertical sorting in chapter 9.

[12] Minty E. J., (2021) *Kosciuszko Ice-Age Heritage*, published on-line with Academia.edu., note figure 9.12.

[13] Minty E. J., (2021) *Kosciuszko Ice-Age Heritage*, published on-line with Academia.edu., note figure 9.5.

[14] Minty E. J. (1989) *Late Pleistocene Geocryology of the Bogong High Plains*, University of Sydney thesis submitted May 1989 (unpublished) note pp382-411.

[15] Washburn A. L., (1975), *Geocryology: A Survey of Periglacial Processes and Environments*, London: Edward Arnold.

[16] Minty E. J., (2021) *Kosciuszko Ice-Age Heritage*, published on-line with Academia.edu., note figure 9.6 and also in the *Kosciuszko Photoglossary KPG-10*.

[17] Barrows T. T., Stone J. O., Fifield L. K. (2004), Exposure ages for Pleistocene deposits in Australia, *Quaternary Science Reviews* **23**:697-708

[18] Caine N., (1983). The Mountains of Northeastern Tasmania. A. A. Balkema, Rotterdam, 200pp